A70-1128-10,000-L180

TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR

COLLEGE STATION, BRAZOS COUNTY, TEXAS

BULLETIN NO. 390 DECEMBER, 1928

DIVISION OF AGRONOMY

EXPERIMENTS WITH FERTILIZERS ON ROTATED AND NON-ROTATED CROPS

AGRICULTURAL AND MECHANICAL COLLEGE OF TEXAS

T. O. WALTON, President

STATION STAFF†

ADMINISTRATION:
A. B. Conner, M. S., *Director*
R. E. Karper, M. S., *Vice-Director*
J. M. Schaedel, *Secretary*
M. P. Holleman, Jr., *Chief Clerk*
J. K. Francklow, *Assistant Chief Clerk*
Chester Higgs, *Executive Assistant*
C. B. Neblette, *Technical Assistant*

CHEMISTRY:
G. S. Fraps, Ph. D., *Chief; State Chemist*
S. E. Asbury, M. S., *Assistant Chemist*
E. C. Carlyle, B. S., *Chemist*
Waldo H. Walker, *Assistant Chemist*
Velma Graham, *Assistant Chemist*
H. S. Osgood, M. S., *Assistant Chemist*
T. L. Ogier, B. S., *Assistant Chemist*
J. G. Evans, *Assistant Chemist*
Athan J. Sterges, B. S., *Assistant Chemist*
G. S. Crenshaw, A. B., *Assistant Chemist*
Jeanne M. Fuegas, *Assistant Chemist*
Hans Platenius, M. Sc., *Assistant Chemist*

HORTICULTURE:
Hamilton P. Traub, Ph. D., *Chief*
H. Ness, M. S., *Berry Breeder*

RANGE ANIMAL HUSBANDRY:
J. M. Jones, A. M., *Chief; Sheep and Goat Investigations*
J. L. Lush, Ph. D., *Animal Husbandman; Breeding Investigations*
Stanley P. Davis, *Wool Grader*

ENTOMOLOGY:
F. L. Thomas, Ph. D., *Chief; State Entomologist*
H. J. Reinhard, B. S., *Entomologist*
R. K. Fletcher, M. A., *Entomologist*
W. L. Owen, Jr., M. S., *Entomologist*
Frank M. Hull, M. S., *Entomologist*
J. C. Gaines, Jr., M. S., *Entomologist*
C. J. Todd, B. S., *Entomologist*
F. F. Bibby, B. S., *Entomologist*
S. E. McGregor, Jr., *Acting Chief Foulbrood Inspector*
Otto Mackensen, *Foulbrood Inspector*

AGRONOMY:
E. B. Reynolds, M. S., *Chief*
R. E. Karper, M. S., *Agronomist; Grain Sorghum Research*
P. C. Mangelsdorf, Sc. D., *Agronomist; in charge of Corn and Small Grain Investigations*
D. T. Killough, M. S., *Agronomist; Cotton Breeding*
H. E. Rea, B. S., *Agronomist; Cotton Root Rot Investigations*
W. E. Flint, B. S., *Agronomist*

PUBLICATIONS:
A. D. Jackson, *Chief*

VETERINARY SCIENCE:
*M. Francis, D. V. M., *Chief*
H. Schmidt, D. V. M., *Veterinarian*
F. E. Carroll, D. V. M., *Veterinarian*

PLANT PATHOLOGY AND PHYSIOLOGY:
J. J. Taubenhaus, Ph. D., *Chief*
W. N. Ezekiel, Ph. D., *Plant Pathologist and Laboratory Technician*
W. J. Bach, M. S., *Plant Pathologist*
J. Paul Lusk, S. M., *Plant Pathologist*
B. F. Dana, M. S., *Plant Pathologist*

FARM AND RANCH ECONOMICS:
L. P. Gabbard, M. S., *Chief*
W. E. Paulson, Ph. D., *Marketing Research Specialist*
C. A. Bonnen, M. S., *Farm Management Research Specialist*
V. L. Cory, M. S., *Grazing Research Botanist*
J. F. Criswell, B. S., *Assistant; Farm Records and Accounts*
**J. N. Tate, B. S., *Assistant; Ranch Records and Accounts*

RURAL HOME RESEARCH:
Jessie Whitacre, Ph. D., *Chief*
Mamie Grimes, M. S., *Textile and Clothing Specialist*
Emma E. Sumner, M. S., *Nutrition Specialist*

SOIL SURVEY:
**W. T. Carter, B. S., *Chief*
E. H. Templin, B. S., *Soil Surveyor*
T. C. Reitch, B. S., *Soil Surveyor*
L. G. Ragsdale, B. S., *Soil Surveyor*

BOTANY:
H. Ness, M. S., *Chief*
Simon E. Wolff, M. S., *Botanist*

SWINE HUSBANDRY:
Fred Hale, M. S., *Chief*

DAIRY HUSBANDRY:
O. C. Copeland, B. S., *Dairy Husbandman*

POULTRY HUSBANDRY:
R. M. Sherwood, M. S., *Chief*

*****AGRICULTURAL ENGINEERING:**

MAIN STATION FARM:
G. T. McNess, *Superintendent*

APICULTURE (San Antonio):
H. B. Parks, B. S., *Chief*
A. H. Alex, B. S., *Queen Breeder*

FEED CONTROL SERVICE:
F. D. Fuller, M. S., *Chief*
S. D. Pearce, *Secretary*
J. H. Rogers, *Feed Inspector*
W. H. Wood, *Feed Inspector*
K. L. Kirkland, B. S., *Feed Inspector*
W. D. Northcutt, Jr., B. S., *Feed Inspector*
Sidney D. Reynolds, Jr., *Feed Inspector*
P. A. Moore, *Feed Inspector*

SUBSTATIONS

No. 1, Beeville, Bee County:
R. A. Hall, B. S., *Superintendent*

No. 2, Troup, Smith County:
P. R. Johnson, B. S., *Act. Superintendent*

No. 3, Angleton, Brazoria County:
R. H. Stansel, M. S., *Superintendent*

No. 4, Beaumont, Jefferson County:
R. H. Wyche, B. S., *Superintendent*

No. 5, Temple, Bell County:
Henry Dunlavy, M. S., *Superintendent*
B. F. Dana, M. S., *Plant Pathologist*
H. E. Rea, B. S., *Agronomist; Cotton Root Rot Investigations*
Simon E. Wolff, M. S., *Botanist; Cotton Root Rot Investigations*

No. 6, Denton, Denton County:
P. B. Dunkle, B. S., *Superintendent*

No. 7, Spur, Dickens County:
R. E. Dickson, B. S., *Superintendent*
W. E. Flint, B. S., *Agronomist*

No. 8, Lubbock, Lubbock County:
D. L. Jones, *Superintendent*
Frank Gaines, *Irrigationist and Forest Nurseryman*

No. 9, Balmorhea, Reeves County:
J. J. Bayles, B. S., *Superintendent*

No. 10, Feeding and Breeding Station, near College Station, Brazos County:
R. M. Sherwood, M. S., *Animal Husbandman in Charge of Farm*
L. J. McCall, *Farm Superintendent*

No. 11, Nacogdoches, Nacogdoches County:
H. F. Morris, M. S., *Superintendent*

****No. 12, Chillicothe, Hardeman County:**
J. R. Quinby, B. S., *Superintendent*
**J. C. Stephens, M. A., *Junior Agronomist*

No. 14, Sonora, Sutton-Edwards Counties:
W. H. Dameron, B. S., *Superintendent*
E. A. Tunnicliff, D. V. M., M. S., *Veterinarian*
V. L. Cory, M. S., *Grazing Research Botanist*
**O. G. Babcock, B. S., *Collaborating Entomologist*
O. L. Carpenter, *Shepherd*

No. 15, Weslaco, Hidalgo County:
W. H. Friend, B. S., *Superintendent*
Sherman W. Clark, B. S., *Entomologist*
W. J. Bach, M. S., *Plant Pathologist*

No. 16, Iowa Park, Wichita County:
E. J. Wilson, B. S., *Superintendent*
J. Paul Lusk, S. M., *Plant Pathologist*

Teachers in the School of Agriculture Carrying Cooperative Projects on the Station:

G. W. Adriance, M. S., *Associate Professor of Horticulture*
S. W. Bilsing, Ph. D., *Professor of Entomology*
V. P. Lee, Ph. D., *Professor of Marketing and Finance*
D. Scoates, A. E., *Professor of Agricultural Engineering*
H. P. Smith, M. S., *Associate Professor of Agricultural Engineering*
R. H. Williams, Ph. D., *Professor of Animal Husbandry*
A. K. Mackey, M. S., *Associate Professor of Animal Husbandry*
J. S. Mogford, M. S., *Associate Professor of Agronomy*

---

†As of December 1, 1928. *Dean, School of Veterinary Medicine.
**In cooperation with U. S. Department of Agriculture.
***In cooperation with the School of Agriculture.

SYNOPSIS

This is a report of experiments conducted over a period of 14 years to study the effect of fertilizers, manure, removal of crop residues, and rotation on the yield of crops. The fertilizer treatments included superphosphate; superphosphate and manure; superphosphate and cottonseed meal; manure; rock phosphate; and rock phosphate and manure. Cotton and corn were grown continuously on the same land and in rotation with oats and cowpeas.

The soil responded more readily to nitrogenous than to phosphatic fertilizers, indicating a deficiency of nitrogen. The increases in yield, however, resulting from the fertilizer treatments were not in general very profitable. Manure was the most profitable treatment on cotton, giving an average yearly profit of $6.36 per acre. None of the fertilizer treatments applied to corn were very profitable; rock phosphate gave the largest profit, which was only 88 cents per acre a year.

Superphosphate and rock phosphate were equally effective in increasing yields, but the rock phosphate was the more profitable because it was less expensive than superphosphate.

The removal of crop residues over a period of 14 years has produced a slight, but not significant, decline in the productiveness of the soil. It is probable, however, that if the practice of removing the residues is continued over a much longer period a significant reduction in yield will occur.

Rotation produced significant increases in the yield of cotton and corn. The yield of cotton was increased 14 per cent and the yield of corn 47.5 per cent in comparison with the yield of continuous cotton and corn, respectively. Rotation produced larger increases in yield than fertilizer, but the largest yields were obtained where rotation and fertilizer were used together. In fact, the increase in yield resulting from the combined use of rotation and fertilizer was greater than the sum of the increases produced by rotation and fertilizer when used separately.

Although rotation increased the yield of cotton and corn, the average acre value of the crops grown in rotation was less than the acre value of continuous cotton. The particular rotation of cotton, cowpeas, corn, and oats, therefore, was not profitable in comparison with continuous cotton, largely on account of the low acre value of cowpeas and oats. A two-year rotation of cotton and suitable feed crops should be satisfactory. Since it is good business to produce the feed required on the farm and since rotation increases the yield of crops, it follows that the crops grown should be included in a rotation. It is clear, therefore, that a rotation costs the farmer nothing provided he uses the most suitable crops for his purpose, and the larger yields resulting from the rotation represent so much gain or profit.

CONTENTS

BULLETIN NO. 390 DECEMBER, 1928

EXPERIMENTS WITH FERTILIZERS ON ROTATED AND NON-ROTATED CROPS

E. B. REYNOLDS

In 1914 the Division of Agronomy, Texas Agricultural Experiment Station, began field experiments to study the effects of fertilizers, manures, green manures, and rotation of crops on the yield and other characters of crops. These experiments have been conducted at the Main Station, College Station, and at the substations in the different parts of the State. The main objects of the experiments conducted at College Station were to determine the effects of fertilizers, manure, removal of crop residues (such as corn stalks, cotton stalks), and rotation on yield of crops. In this Bulletin are reported the results obtained at College Station with cotton, corn, oats, and cowpeas, for the 14 years, 1914 to 1927.

The field experiments at the Main Station, College Station, have been conducted on Lufkin fine sandy loam soil. The surface soils of the Lufkin series are gray to ashy gray in color, while the subsoils are gray or mottled grayish and yellowish, and range in texture from compact sand to impervious, plastic clay. The topography is either flat, undulating or rolling, and this, together with the impervious nature of the subsoil, results in poor drainage both on the surface and through the soil. The poor drainage through the soil is perhaps the most characteristic feature of the Lufkin soils. Some of these soils, particularly in Brazos county, have fairly good surface drainage. The Lufkin soils are low in organic matter and nitrogen. In the virgin state these soils are forested, the heavier types mainly with post oak, and the more sandy types with pine and mixed hardwood. The Lufkin soils are developed more or less extensively in east-central Texas, in the western part of the section sometimes called the "flat-woods." They occur in Angelina, Polk, Houston, Trinity, San Jacinto, Walker, Montgomery, Madison, Brazos, and Grimes counties. While the Lufkin soils occur rather extensively in these counties, other soils, such as the Ruston and Norfolk, also occur. The results of the fertilizer experiments on the Lufkin fine sandy loam should be applicable generally to the Lufkin soils of the region.

PLAN OF THE EXPERIMENT

The field work consists of a four-year rotation of cotton, cowpeas, corn, and oats followed by cowpeas as a catch crop, and continuous cotton and continuous corn. Six blocks of land, each consisting of 10 one-tenth acre plats, exclusive of border or guard rows, are used. The blocks of land are designated as B, C, D, E, F, and G (Table 1). Block B has grown corn and Block G has grown cotton, every year.

Table 1.—Arrangement of plats and blocks of land in fertilizer experiment.

Plat No.	Block G Cotton every year	Block F Corn 1914-18-22	Block E Cowpeas 1914-18-22	Block D Cotton 1914-18-22	Block C Oats 1914-18-22	Block B Corn every year
10	No treatment	No treatment	No treatment	No treatment	No treatment	No treatment
9	Rock phosphate and manure	Rock phosphate and manure	Rock phosphate and manure	Rock phosphate and manure	Rock phosphate and manure	Rock phosphate and manure
8	Rock phosphate	Rock phosphate	Rock phosphate	Rock phosphate	Rock phosphate	Rock phosphate
7	Manure and superphosphate	Manure and superphosphate	Manure and superphosphate	Manure and superphosphate	Manure and superphosphate	Manure and superphosphate
6	No treatment	No treatment	No treatment	No treatment	No treatment	No treatment
5	Manure	Manure	Manure	Manure	Manure	Manure
4	Superphosphate	Superphosphate	Superphosphate	Superphosphate	Superphosphate	Superphosphate
3	No treatment	No treatment	No treatment	No treatment	No treatment	No treatment
2	Residues removed	Residues removed	Residues removed	Residues removed	Residues removed	Residues removed
1	Cottonseed meal Superphosphate	Cottonseed meal Superphosphate	Cottonseed meal Superphosphate	Cottonseed meal Superphosphate	Cottonseed meal Superphosphate	Cottonseed meal Superphosphate

The four-year rotation of cotton, cowpeas, corn, and oats occupies Blocks C, D, E, and F. Cotton occupied Block D in 1914, Block C in 1915, Block F in 1916, Block E in 1917, and in 1918, the fifth year of the rotation, cotton again occupied Block D. The other crops followed in regular order.

Size of Plats

The plats consist of 13 rows, each row being 3 feet wide and 132 feet long. The first row and the last row of each plat serve as border or guard rows, which are discarded at harvest time. These guard rows are used to prevent the treatment on one plat from affecting the yield on adjacent plats. The area harvested on each plat, therefore, consists of 11 rows, or one-tenth acre.

Fertilizer Treatments

The fertilizer treatments of the experiment, as originally outlined and as conducted until 1922, are shown below. These treatments were applied to crops grown in rotation.

Plat No.	Treatment Per Acre
1	200 pounds superphosphate* and 100 pounds cottonseed meal
2	Crop residues removed
3	No treatment—check
4	200 pounds superphosphate
5	5 tons manure (applied to cotton only)
6	No treatment—check
7	5 tons manure and 200 pounds superphosphate (applied to cotton only)
8	Ground rock phosphate equal to the amount of phosphoric acid in 200 pounds of superphosphate
9	5 tons manure and ground rock phosphate equal to the amount of phosphoric acid in 200 pounds of superphosphate (applied to cotton only)
10	No treatment—check

*Superphosphate is the same as acid phosphate. The term superphosphate has been adopted by the fertilizer industry.

The above treatments were applied also to the continuous cotton and corn, except that the treatments of rock phosphate and manure were omitted entirely and the treatment of manure and superphosphate was not applied to the same plat each year; the first year it was on plat 5, the second year on plat 7, the third year on plat 8, the fourth year on plat 9, and the fifth year on plat 5 again.

Since all of the treatments of the rotated and continuous crops were not comparable, as pointed out above, the plan of the experiment was changed in 1922 so as to make the treatments on all the blocks uniform.

That is, the treatment of Plat 1 on Blocks B, C, D, E, F, and G would be the same; the treatments on Plat 2 of all six blocks would be the same; and the other plats were treated in a similar manner as shown in Table 1. The revised plan in detail is shown below and the treatments shown are applied to each of the six blocks every year.

Plat No.	Treatment Per Acre
1	200 pounds superphosphate and 100 pounds cottonseed meal
2	Crop residues removed
3	No treatment—check
4	200 pounds superphosphate
5	4 tons manure
6	No treatment—check
7	4 tons manure and 200 pounds superphosphate
8	Ground rock phosphate equal to the amount of phosphorus in 200 pounds of superphosphate
9	4 tons manure and Ground rock phosphate equal to the amount of phosphorus in 200 pounds of superphosphate
10	No treatment—check

It will be noted that the only difference between the old plan and the revised plan is that all of the treatments are applied to each crop every year, that rock phosphate is applied also to the non-rotated cotton and corn, and that the manure is applied at the rate of 4 tons per acre every year instead of 5 tons every four years. This treatment of manure thus supplies 16 tons of manure every four years instead of 5 tons, or more than three times as much as furnished by the original plan.

It should be pointed out that 107 pounds of the ground rock phosphate used contained the same amount of phosphorus as the 200 pounds of 16 per cent superphosphate. In the following tables reporting the yields of the crops, the amount of rock phosphate is given as 107 pounds rather than rock phosphate equal to 200 pounds of superphosphate.

Plowing the Land

In the earlier years of the experiment, plowing was done across the blocks, each plat being plowed as a unit, with a back furrow in the center to provide good surface drainage. This method of plowing soon provided the necessary drainage. After adequate drainage was provided on the plats, plowing was done across the plats either with a two-way plow, turning the furrow slice in one direction or with a single moldboard plow dragging around the ends, to avoid turning within the experimental area.

Time and Method of Applying Fertilizer and Manure

The time and method of applying the fertilizer materials has been rather variable. During the first years of the experiment the fertilizer was applied along the row with a fertilizer distributor at planting time or two or three weeks after planting in the case of cotton, corn, and cowpeas. From 1922 to 1927, inclusive, the fertilizers were applied broadcast two or three weeks before planting.

The materials have been applied broadcast to the oats. The manure has always been applied before planting and disked into the surface soil. Previous to 1922 the fertilizer was applied broadcast early in the spring to the fall-planted oats. Since 1922 the fertilizers have been applied to the land before planting the oats.

Disposal of Crop Residues

On Plat 2 of all six blocks the crop residues have been removed after harvesting the corn, cotton, and cowpeas and before plowing the land for succeeding crops. The oat stubble has not been removed. The oat-stubble land, however, was plowed as soon as practicable after harvest and the land seeded to cowpeas as a catch crop for soil improvement.

Influence of Rainfall

The average rainfall at different places in the region, as published by the United States Weather Bureau, "Climatological Data: Texas Section," is given here.

Station	County	Average Rainfall, Inches	Number of Years
College Station	Brazos	38.21	38
Huntsville	Walker	42.94	44
Lufkin	Angelina	44.09	20
Navasota	Grimes	39.61	13

The average yearly rainfall at the Experiment Station, College Station, Texas, was 39.63 inches for the 14 years, 1914 to 1927, inclusive, during which the fertilizer experiment was conducted, as shown in Table 2. The table also shows the distribution of rainfall by months during the period. The average rainfall at College Station, and also at the other places mentioned above, would appear to be sufficient for satisfactory yields of crops; yet the distribution of rainfall is not always favorable for the production of large yields. Sometimes drouths occur during the growing season and reduce the yield of crops. For instance, in 1917 and 1925 the rainfall was so deficient during the growing season of corn that the crop was a failure. Low yields of cotton resulted in 1917 and 1918 for the same reason.

Table 2.—Rainfall in inches at the Experiment Station, College Station, 1914 to 1927, inclusive.

Month	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	Average
Total	38.92	43.92	28.05	15.50	34.53	57.00	47.69	43.25	43.50	48.71	33.09	31.47	47.93	41.28	39.63
Total for June, July and August	7.74	17.42	5.33	3.08	4.43	18.49	17.22	11.74	6.12	4.60	3.15	5.33	5.98	8.50	8.51
January	0.55	2.63	5.90	1.86	1.96	4.12	6.35	2.09	5.39	3.28	4.24	1.72	4.37	1.63	3.29
February	2.58	0.59	0.00	2.21	4.39	6.58	0.80	1.88	4.13	4.80	6.51	0.62	0.21	6.25	2.97
March	5.40	1.85	0.36	0.45	0.62	2.55	1.40	4.15	3.95	6.35	2.67	0.38	8.09	2.88	2.94
April	2.95	16.90	0.83	2.74	4.78	1.32	0.64	12.60	7.28	4.01	6.22	1.95	4.79	6.63	5.26
May	7.61	0.00	11.55	1.86	2.52	8.28	5.97	1.84	9.31	3.80	6.18	0.02	4.51	1.80	4.66
June	0.12	3.08	2.94	0.00	2.73	9.01	5.09	10.90	4.56	0.66	1.75	1.67	0.90	5.01	3.46
July	0.49	0.69	1.59	0.60	0.47	4.07	4.64	0.64	0.58	2.32	1.28	1.12	3.16	3.47	1.79
August	7.13	13.65	0.80	2.48	1.23	5.41	7.49	0.20	0.98	1.62	0.12	2.54	1.92	0.02	3.26
September	0.37	0.45	0.81	2.09	0.81	3.26	3.63	3.67	1.72	4.84	1.06	3.02	0.91	0.71	1.95
October	0.57	0.00	1.35	0.16	5.72	8.19	6.30	0.16	1.82	3.37	0.26	11.62	7.21	8.40	3.94
November	6.57	0.00	1.56	0.99	5.83	2.45	3.00	0.38	3.03	5.33	1.08	5.82	2.38	0.33	2.77
December	4.58	4.08	0.36	0.06	3.47	1.76	2.38	4.74	0.75	8.33	1.72	0.99	9.48	4.15	3.35
Average monthly	3.24	3.66	2.33	1.29	2.87	4.75	3.97	3.60	3.62	4.06	2.75	2.62	3.99	3.44	3.30

EFFECT OF FERTILIZERS ON YIELD OF CROPS

The effect of fertilizers on the yield of each crop is discussed separately. The yield of crops grown in rotation and the yield of crops grown continuously on the same land are also considered separately. Then the results of the two systems of cropping are brought together and compared directly.

Cotton

The experiment included cotton grown in rotation and cotton grown on the same land every year. In any year the same variety of cotton was used in both systems of cropping. The same variety, however, was not used every year of the experiment. The Hendricks variety was planted in 1916, while Lone Star or strains of Lone Star have been grown in the test since 1916. The spacing of cotton has varied somewhat during the experiment, but for any year the spacing was the same for both rotated and continuous cotton. In most years the spacing was one plant every 12 inches in the row, but in 1923 the spacing was 18 inches. The spacing of 12 inches in rows 3 feet apart provides 14,520 plants per acre. The rotated cotton was a failure in 1920, due primarily to late germination of the seed, and, as a consequence, the cotton failed to mature before frost.

Yield of Cotton in Rotation

The results secured with rotated cotton are presented in Table 3. Only five of the treatments occurred every year of the experiment. Of these five treatments, the application of 4 tons of manure and 200 pounds superphosphate* made the highest average yield, 204 pounds of lint per acre for the 14 years. The treatment of 4 tons of manure made about as large yield, 201 pounds per acre.

For the 13 years, 1914 to 1927, omitting 1920, the treatment of cottonseed meal with superphosphate produced an average yield of 205 pounds of lint; manure with superphosphate, 220 pounds; and the manure alone, 216 pounds of lint per acre. These were the only treatments that produced yields significantly greater than the yield of the plats which received no treatment, according to Student's method. As pointed out in Table 4, the chances, or odds, are 105.9 to 1 that the difference in the yield produced by the treatment of manure and superphosphate and the yield produced by the untreated plats is significant. Usually it is considered that the odds must be 22 or more to 1 to indicate a significant difference. It seems certain, therefore, that this difference in yield is due to the treatment and not to chance or difference in soil.

---

*Previous to 1922 this treatment consisted of 5 tons of manure and 200 pounds of superphosphate and was applied to cotton only, the other crops in the rotation receiving the residual effect. Since 1922 the treatment has been 4 tons of manure and 200 pounds of superphosphate and has been applied to each of the four crops in the rotation.

Table 3.—Yield of rotated cotton in fertilizer experiment at College Station 1914 to 1927, inclusive.

Fertilizer Treatment Pounds Per Acre	Yield in Pounds of Lint Per Acre													Average		
	1914	1915	1916	1917	1918	1919	1921	1922	1923	1924	1925	1926	1927	1914–1927	1914–1927*	1922–1927
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
100 lbs. cottonseed meal 200 lbs. superphosphate...	301	256	302	33	113	241	119	222	228	201	236	263	156	191	205	218
Crop residues removed...	267	240	310	29	74	107	80	203	199	193	201	263	113	163	175	195
No treatment—check.....	292	233	216	32	83	231	113	226	213	247	195	240	117	174	188	206
200 lbs. superphosphate...	304	237	220	30	74	247	107	224	203	246	204	270	106	177	190	209
4 tons manure...........	267	222	235	33	87	240	124	227	302	303	220	342	211	201	216	268
4 tons manure 200 lbs. superphosphate...	319	236	249	35	88	254	146	242	351	245	185	288	217	204	220	255
107 lbs. rock phosphate ...	......	......	......	23	......	220	133	259	179	231	181	289	159	......	......	216
107 lbs. rock phosphate 4 tons manure..........	......	......	......	......	......	......	100	260	166	234	186	302	179	......	......	221

*Omitting 1920.

The data in Table 3 show there was little difference in the yields produced by superphosphate and rock phosphate. The yields of these treatments were not significantly greater than the yield of the plats which received no treatment, during the six years, 1922 to 1927, inclusive.

All of the treatments except superphosphate and the untreated check plats made significantly larger yields than the plats from which the crop residues were removed. The check plats produced an average yield of 174 pounds of lint per acre and the plats with the residues removed produced 163 pounds per acre for the 14 years. While this is a difference of 11 pounds per acre a year, it is not statistically significant, as shown by the odds in Table 4.

Table 4.—Comparison by Student's method of yields of rotated cotton treated with different fertilizers.

Greater Yield	Smaller Yield	Odds	No. of Years Treatments Were Compared
Cottonseed meal and superphosphate.	No treatment	35.8 : 1	13
No treatment	Crop residues removed	4.3 : 1	13
Superphosphate	No treatment	3.5 : 1	13
Manure	No treatment	65.0 : 1	13
Manure and superphosphate	No treatment	105.9 : 1	13
Rock phosphate	No treatment	2.9 : 1	9
Rock phosphate and manure	No treatment	2.9 : 1	7
Cottonseed meal and superphosphate.	Crop residues removed	210.0 : 1	13
Cottonseed meal and superphosphate.	Superphosphate	17.7 : 1	13
Manure and superphosphate	Cottonseed meal and superphosphate	5.7 : 1	13
Cottonseed meal and superphosphate.	Rock phosphate	1.0 : 1	9
Rock phosphate and manure	Cottonseed meal and superphosphate	1.0 : 1	7
Manure	Cottonseed meal and superphosphate	33.7 : 1	13
Superphosphate	Crop residues removed	5.5 : 1	13
Manure and superphosphate	Crop residues removed	78.5 : 1	13
Manure	Crop residues removed	66.2 : 1	13
Rock phosphate	Crop residues removed	34.4 : 1	9
Rock phosphate and manure	Crop residues removed	16.6 : 1	7
Manure	Superphosphate	37.2 : 1	13
Manure and superphosphate	Superphosphate	42.4 : 1	13
Rock phosphate	Superphosphate	1.9 : 1	9
Rock phosphate and manure	Superphosphate	2.7 : 1	7
Manure and superphosphate	Rock phosphate	14.7 : 1	9
Manure and superphosphate	Rock phosphate and manure	7.5 : 1	7
Rock phosphate and manure	Rock phosphate	4.8 : 1	6
Manure	Rock phosphate and manure	19.9 : 1	6
Manure and superphosphate	Manure	1.0 : 1	13
Manure	Rock phosphate	42.5 : 1	9

The treatment of 4 tons of manure made the highest average yield, 268 pounds of lint per acre, for the six years, 1922 to 1927. Manure with superphosphate ranked second, with an average yield of 255 pounds per acre. This small difference in yield is not significant. The manure, however, was the most profitable treatment, as will be shown later. The manure alone made significantly larger yields than the treatment of cottonseed meal and superphosphate.

The results in Table 3 show that manure alone was the best treatment used. The results also show that nitrogen in the form of manure produced larger yields than phosphoric acid, either in the form of superphosphate or rock phosphate. This is confirmed further by the fact that the addition of superphosphate to the manure or superphosphate with cottonseed meal did not produce larger yields than the manure alone. Apparently the soil did not respond readily to applications of phosphoric acid as indicated by the yields of rotated cotton.

In the preceding paragraphs the fertilizer treatments were discussed in relation to yield. It is desirable to know also the profits or losses that may be expected from the use of fertilizers. Accordingly, the profits and losses resulting from the fertilizer treatments used were computed. The losses or gains produced by the treatments were determined by subtracting the cost of the fertilizer from the value of the increase produced by the treatment.

The prices of cottonseed meal and superphosphate were taken from Texas Station Bulletins 298, 312, 322, 335, 346, and 368. The manure was figured at $1.25 a ton. Rock phosphate is usually not sold on the retail market and for this reason retail prices are not available. Some rock phosphate, however, was bought at $12.00 a ton in 1925 and this price was used in calculating the profit or loss resulting from rock phosphate. The estimated price of cotton for December 1 of each year as given in the year books of the United States Department of Agriculture were used in computing the value of the cotton. Table 5 gives the profits or losses resulting from the different fertilizer treatments during the six years, 1922 to 1927, inclusive.

Table 5.—Profit or loss per acre attributable to different fertilizer treatments applied to cotton in rotation.

Fertilizer Treatment	1922	1923	1924	1925	1926	1927	Average
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
100 lbs. cottonseed meal 200 lbs. superphosphate ..	-4.88	-0.48	-4.40	3.46	-1.29	3.82	-0.63
Crop residues removed...	-5.41	-4.26	-12.10	1.11	2.48	-0.77	-3.16
200 lbs. superphosphate...	-2.32	-2.34	-2.30	-0.68	0.99	-2.12	-1.46
4 tons manure..........	-4.76	22.06	7.54	-0.37	6.02	13.14	7.27
4 tons manure 200 lbs. superphosphate...	-3.56	34.61	-7.30	-7.35	-2.07	12.18	4.42
107 lbs. rock phosphate ..	7.10	-0.65	-0.65	-0.65	4.64	7.46	2.87
107 lbs. rock phosphate 4 tons manure..........	2.34	-5.65	-5.65	-5.65	1.05	6.32	-1.21

The application of 4 tons of manure made an average profit of $7.27 per acre, and was the most profitable treatment used. Manure with superphosphate was the next most profitable treatment, producing an average yearly profit of $4.42 per acre. Rock phosphate at the rate of 107 pounds per acre (equivalent to the phosphoric acid in 200 pounds of 16 per cent superphosphate) made a profit of $2.87 per acre, as compared with an average loss of $1.46 per acre for superphosphate. The other treatments were used at losses ranging from $0.63 to $3.16 per acre.

Yield of Continuous Cotton

The yields of cotton grown on the same land every year, that is, continuous cotton, are shown in Table 6. Yields were obtained from only five of the eight treatments every year, since the treatments of manure alone, rock phosphate, and manure and rock phosphate began in 1922. The application of 200 pounds of superphosphate made the highest average yield, 193 pounds of lint per acre, for the 14 years of the experiment. The treatments of cottonseed meal with superphosphate and manure with superphosphate ranked next with an average yield of 182 and 180 pounds of lint per acre, respectively, for the 14 years, and the same average yield, 181 pounds, for the 13 years. There were no significant differences in the yield of these three treatments as shown by the odds in Table 7. The yields of these treatments were significantly greater than the yield of the check plats which received no treatment and were also greater than the yield of the plats from which the residues were removed. The plats with the crop residues removed made an average yearly yield of 157 pounds of lint per acre for the 14 years and the check plats which received no treatment made an average yearly yield of 161 pounds. This slight difference in yield was not significant, as shown in Table 7, indicating that the removal of crop residues for a period of 14 years did not produce a significant decline in the productiveness of the soil. In fact, for the last six years the average yields were practically identical, being 176 and 177 pounds per acre, respectively.

The superphosphate made an average yield of 207 pounds of lint per acre and the rock phosphate made 212 pounds for the six years, 1922 to 1927, inclusive. The difference in yield was not significant as shown by the odds in Table 7.

During the six years, 1922 to 1927, the manure alone produced the highest average yield, 225 pounds of lint per acre. This yield was significantly greater than the yield of 206 pounds made by the manure and superphosphate. It was the best and one of the most profitable treatments used, as was also the case with the rotated cotton.

The profits resulting from the fertilizer treatments applied to cotton grown on the same land every year during the six years, 1922 to 1927, are shown in Table 8. The profits or losses in this table were determined by subtracting the cost of the fertilizer treatment from the value of the increase produced by the treatment.

Table 6.—Yield of continuous cotton in fertilizer experiment at College Station, 1914 to 1927, inclusive.

Fertilizer Treatments	Yield in Pounds of Lint Per Acre.														Average		
	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1914–1927	1914–1927*	1922–1927
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
100 lbs. cottonseed meal 200 lbs. superphosphate.......	302	204	237	32	85	89	193	100	201	240	232	59	381	188	182	181	217
Crop residues removed......	268	208	201	37	76	63	192	90	125	268	176	57	288	142	157	154	176
No treatment—check.......	237	199	212	36	88	104	210	109	144	232	188	53	288	158	161	158	177
200 lbs. superphosphate.......	267	210	317	34	73	131	272	148	235	236	222	57	323	170	193	186	207
4 tons manure....	......	......	......	......	......	......	......	......	219	268	216	60	387	202	......	......	225
4 tons manure 200 lbs. superphosphate.......	300	185	229	21	95	146	167	133	205	234	204	51	346	198	180	181	206
107 lbs. rock phosphate.......	......	......	......	......	......	......	......	......	226	228	216	47	379	176	......	......	212
107 lbs. rock phosphate 4 tons manure....	......	......	......	......	......	......	......	......	166	240	234	49	363	186	......	......	206

*Omitting 1920.

Table 7.—Comparison by Student's method of yields of continuous cotton treated with different fertilizers.

Greater Yield	Smaller Yield	Odds	No. of Years Treatments Were Compared
Cottonseed meal and superphosphate.	No treatment.	47.9 : 1	14
No treatment.	Crop residues removed.	4.0 : 1	14
Superphosphate.	No treatment.	385.8 : 1	14
Manure.	No treatment.	118.5 : 1	6
Manure and superphosphate.	No treatment.	38.7 : 1	14
Rock phosphate.	No treatment.	19.1 : 1	6
Rock phosphate and manure.	No treatment.	37.1 : 1	6
Cottonseed meal and superphosphate.	Crop residues removed.	123.1 : 1	14
Superphosphate.	Cottonseed meal and superphosphate.	5.0 : 1	14
Manure.	Cottonseed meal and superphosphate.	7.7 : 1	6
Cottonseed meal and superphosphate.	Manure and superphosphate.	1.0 : 1	14
Cottonseed meal and superphosphate.	Rock phosphate.	3.2 : 1	6
Cottonseed meal and superphosphate.	Manure and rock phosphate.	14.6 : 1	6
Superphosphate.	Crop residues removed.	177.7 : 1	14
Manure.	Crop residues removed.	51.7 : 1	6
Manure and superphosphate.	Crop residues removed.	43.2 : 1	14
Rock phosphate.	Crop residues removed.	10.7 : 1	6
Rock phosphate and manure.	Crop residues removed.	15.4 : 1	6
Manure.	Superphosphate.	9.2 : 1	6
Superphosphate.	Manure and superphosphate.	6.6 : 1	14
Rock phosphate.	Superphosphate.	2.0 : 1	6
Superphosphate.	Rock phosphate and manure.	1.0 : 1	6
Manure.	Manure and superphosphate.	75.5 : 1	6
Manure.	Rock phosphate.	15.8 : 1	6
Manure.	Manure and rock phosphate.	18.6 : 1	6
Rock phosphate.	Manure and superphosphate.	2.9 : 1	6
Rock phosphate and manure.	Manure and superphosphate.	1.0 : 1	6
Rock phosphate.	Rock phosphate and manure.	2.1 : 1	6

Table 8.—Profit or loss per acre attributable to different fertilizer treatments applied to continuous cotton.

Fertilizer Treatment	1922	1923	1924	1925	1926	1927	Average
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
100 lbs. cottonseed meal 200 lbs. superphosphate.	8.52	–2.61	5.46	–3.02	6.27	2.08	2.78
Crop residues removed.	–4.47	10.94	–2.69	0.74	0.00	–3.09	0.24
200 lbs. superphosphate.	19.07	–1.12	5.32	–1.61	1.53	0.20	3.90
4 tons manure.	12.63	5.94	1.27	3.70	5.69	3.49	5.45
4 tons manure 200 lbs. superphosphate.	7.02	–6.73	–3.72	–7.35	–0.99	0.60	–1.86
107 lbs. rock phosphate.	18.62	–0.65	5.62	–0.65	9.18	2.82	5.82
107 lbs. rock phosphate 4 tons manure.	–0.48	–3.22	4.65	–5.65	2.45	–0.25	–0.42

Rock phosphate produced the greatest profit, $5.82 per acre, and the manure alone produced the second largest gain, $5.45 per acre, for the six-year period. Superphosphate made an average yearly gain of $3.90 per acre and the cottonseed meal and superphosphate $2.78 per acre.

Manure with superphosphate and manure with rock phosphate were the only treatments that were used at a loss. The former made a yearly loss of $1.86 per acre for the six years, while the latter produced an average yearly loss of $0.42 per acre. These two treatments produced the same average yields and the difference in the losses was caused mainly by the difference in cost of the superphosphate and rock phosphate.

Comparison of Rotated and Continuous Cotton

In the preceding paragraphs the results obtained with rotated and continuous cotton were discussed separately. The average yields and profits resulting from the different treatments on both the rotated and continuous cotton are brought together in Table 9, so that the results of the two methods may be compared more readily.

The average yields of lint produced by the several treatments in both rotated and continuous cotton for 13 years and for six years are given in Table 9.

Table 9.—Comparison of yields and profits per acre attributable to fertilizer treatments applied to rotated and continuous cotton.

Fertilizer Treatment	Average Yield of Lint Per Acre for				Average Profit or Loss from Fertilizer Treatment for Six Years, 1922–1927	
	13 Years 1914–1927*		6 Years 1922–1927			
	Rotated	Continuous	Rotated	Continuous	Rotated	Continuous
	Pounds	Pounds	Pounds	Pounds	Dollars	Dollars
100 lbs. cottonseed meal 200 lbs. superphosphate	205	181	218	217	–0.63	2.78
Crop residues removed	175	154	195	176	–3.16	0.24
No treatment—check	188	158	206	177	....	....
200 lbs. superphosphate	190	186	209	207	–1.46	3.90
4 tons manure	....	....	268	225	7.27	5.45
4 tons manure 200 lbs. superphosphate	220	181	255	206	4.42	–1.86
107 lbs. rock phosphate	....	....	216	212	2.87	5.82
107 lbs. rock phosphate 4 tons manure	....	....	221	206	–1.21	–0.42
Average	196	172	224	203	1.01	1.99

*Omitting 1920 on account of failure of rotated cotton.

As an average of all the treatments, the rotated cotton produced 196 pounds of lint per acre a year, or 24 pounds per acre more than the continuous cotton, for the 13 years. For the six years, 1922 to 1927, inclusive, the rotated cotton produced an average yield of 224 pounds per acre, or 21 pounds more than the continuous cotton. There was only one treatment, the manure with superphosphate, that produced significantly larger yields when applied to the rotated cotton than it did on continuous cotton, according to Student's method as shown in Table 10. In this case the odds or chances are 81 to 1 that the yield of the rotated cotton, 220 pounds per acre, was greater than the yield of 181 pounds for the continuous cotton. During the six years, 1922 to 1927, inclusive, the treatment of manure alone produced an average yield of 268 pounds of lint per acre when applied to rotated cotton and 225 pounds on continuous cotton. This is a difference of 43 pounds per acre a year, which is not significant according to Student's method on account of the fact that the rotated cotton did not produce consistently larger yields than the continuous cotton and to the short period of years; yet in farm practice this difference in yield would be considered significant.

Table 10.—Comparison by Student's method of yields of cotton grown continuously on the same land and in rotation receiving fertilizer treatments.

Treatment	Greater Yield	Smaller Yield	Odds	No. of Years Treatments Were Compared
Cottonseed meal and superphosphate....	Rotated	Continuous	6.2 : 1	13
Crop residues removed..................	Rotated	Continuous	7.42 : 1	13
No treatment...........................	Rotated	Continuous	19.06 : 1	13
Superphosphate.........................	Rotated	Continuous	1.0 : 1	13
Manure.................................	Rotated	Continuous	8.38 : 1	6
Manure and superphosphate..............	Rotated	Continuous	81.4 : 1	13
Rock phosphate.........................	Rotated	Continuous	1.0 : 1	6
Rock phosphate and manure..............	Rotated	Continuous	1.91 : 1	6

The average profits and losses produced by the different treatments during the six years, 1922 to 1927, inclusive, are shown in Table 9. As mentioned previously, the gains and losses were found by subtracting the cost of the fertilizer from the value of the increase produced by the treatment. The manure was the most profitable treatment used, since it made a profit of $7.27 per acre on rotated cotton and $5.45 per acre on continuous cotton. The treatment of rock phosphate alone, however, made the largest profit, $5.82 per acre, on the continuous cotton.

Corn

Rotated corn and continuous corn were included in the experiment, as was pointed out in discussing the plant of the experiment. The same variety of corn was not grown in the experiment every year. Fentress Strawberry was planted in 1914, 1923, and 1924. Mosby's Prolific was grown in 1916 and 1917. Surcropper was planted in the experiment four years, 1919, 1920, 1921, and 1922, while Chisholm was included in 1926 and 1927. Usually the stand of corn was one plant every 3 feet in the row, or 4840 plants per acre. The corn in the experiment was a complete failure in 1917 and 1925 on account of extreme drouth. These two years are considered, however, in computing the average yields during the period of the experiment.

Yield of Corn in Rotation

The yields obtained with the corn in the rotation are shown in Table 11. It will be observed that yields were obtained from only four of the eight treatments for the 12 years. Reasonably good yields were made in 1916, 1921, 1922, and 1927. Excellent yields resulted in 1919 and 1920, considering the fact that the soil is naturally not very productive. Yields below the average for the 14 years were made in 1918, 1923, 1924, and 1926. As mentioned above, the corn was a failure in 1917 and 1925, on account of drouth.

The treatment of 100 pounds of cottonseed meal and 200 pounds of superphosphate made the highest average yield, 25.9 bushels, during the 14 years of the experiment. This yield is significantly greater than the yield of the untreated check plats, the yield of the plats treated with superphosphate alone, and greater than the yield of the plats on which the residues (cotton stalks, corn stalks, etc.) were removed. (See Table 12.) During this period the untreated check plats produced an average yield of 21.8 bushels per acre and plats with the crop residues removed made 21.2 bushels per acre; while for the last six years of the experiment the former produced an average yield of 21.5 bushels and the latter 20.2 bushels per acre. This small difference in yield is not significant from a statistical standpoint; yet it shows that the removal of crop residues is reducing slightly the productiveness of the soil.

During the nine years, 1918 to 1927, excluding 1925, the treatments of cottonseed meal with superphosphate and manure alone made the highest average yield, 30.8 and 30.7 bushels per acre, respectively. The manure reinforced with 200 pounds of superphosphate gave the next highest yield, 28.2 bushels per acre. Superphosphate made an average yield of 26.8 bushels, as compared with 24.3 bushels per acre for the rock phosphate.

All of the treatments were applied to the corn during the six years, 1922 to 1927, inclusive, but the corn was a failure in 1925 on account of drouth and this year is not included in the average. The treatment of manure alone produced the highest average yield, 27.2 bushels per acre, while the application of cottonseed meal and superphosphate ranked second with a yield of 26.0 bushels. This difference in yield, 1.2 bushels, is not significant. The application of 200 pounds of superphosphate gave a yield of 22.7 bushels per acre for the five years. The addition of 100 pounds of cottonseed meal per acre to the superphosphate increased the yield from 22.7 to 26.0 bushels per acre, which is a significant increase.

The yields of the different treatments on rotated corn show that manure alone made the highest yield, but it was unprofitable as will be shown later. The large yield of the manure appears to be due to the nitrogen in the manure since the addition of superphosphate to manure did not increase the yield. That this larger yield is due to the nitrogen is indicated further by the fact that the addition of cottonseed meal to superphosphate produced significant increase in yield over

Table 11.—Yield of rotated corn in fertilizer experiment at College Station, 1914 to 1927, inclusive.

Fertilizer Treatment	Yield in Bushels Per Acre															
													Average			
	1914	1915	1916	1918	1919	1920	1921	1922	1923	1924	1926	1927	1914–1927	1914–1927*	1918–1927**	1922–1927**
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
100 lbs. cottonseed meal 200 lbs. superphosphate..	28.4	28.6	27.7	22.3	49.7	34.4	40.9	38.2	15.0	15.9	25.5	35.5	25.9	30.2	30.8	26.0
Crop residues removed...	25.9	24.8	26.3	21.5	40.4	30.5	26.3	29.4	5.4	14.4	20.1	31.8	21.2	24.7	24.4	20.2
No treatment..........	18.8	21.2	30.1	17.9	38.4	43.4	28.1	30.7	9.8	16.9	15.8	34.3	21.8	25.5	26.1	21.5
200 lbs. superphosphate..	19.6	23.9	29.9	18.9	36.6	42.2	30.4	34.6	11.4	17.5	15.3	34.5	22.5	26.2	26.8	22.7
4 tons manure..........	......	......	30.8	15.9	35.3	58.4	31.3	39.7	17.7	20.4	22.3	35.7	......	......	30.7	27.2
4 tons manure 200 lbs. superphosphate..	......	......	33.1	14.8	39.4	44.6	34.0	28.0	12.7	21.0	28.2	30.8	......	......	28.2	24.1
107 lbs. rock phosphate...	......	......	33.9	14.9	30.7	32.1	34.6	23.8	11.3	18.4	20.0	33.3	......	......	24.3	21.4
107 lbs. rock phosphate 4 tons manure..........	......	......	......	16.0	39.9	34.9	27.8	31.2	13.9	20.6	20.6	23.6	......	......	25.4	22.0

*Omitting 1917 and 1925. **Omitting 1925.

the superphosphate alone. From these results it is concluded that the soil needs nitrogen first, responding readily to cottonseed meal, and manure, and that phosphoric acid did not increase the yield of corn appreciably.

Table 12.—Comparison by Student's method of yields of rotated corn treated with different fertilizers.

Greater Yield	Smaller Yield	Odds	No. of Years Treatments Were Compared
Cottonseed meal and superphosphate	Crop residues removed	1865.8 : 1	12
Cottonseed meal and superphosphate	No treatment	67.8 : 1	12
Cottonseed meal and superphosphate	Superphosphate	40.2 : 1	12
Cottonseed meal and superphosphate	Manure	1.0 : 1	10
Cottonseed meal and superphosphate	Manure and superphosphate	3.7 : 1	10
Cottonseed meal and superphosphate	Rock phosphate	35.7 : 1	10
Cottonseed meal and superphosphate	Rock phosphate and manure	77.3 : 1	9
No treatment	Crop residues removed	2.1 : 1	12
Superphosphate	Crop residues removed	4.9 : 1	12
Manure	Crop residues removed	25.4 : 1	10
Manure and superphosphate	Crop residues removed	28.3 : 1	10
Rock phosphate	Crop residues removed	1.8 : 1	10
Rock phosphate and manure	Crop residues removed	2.4 : 1	9
Superphosphate	No treatment	15.8 : 1	12
Manure	No treatment	38.1 : 1	10
Manure and superphosphate	No treatment	8.9 : 1	10
No treatment	Rock phosphate	2.8 : 1	10
No treatment	Rock phosphate and manure	1.9 : 1	9
Manure	Superphosphate	29.8 : 1	10
Manure and superphosphate	Superphosphate	3.9 : 1	10
Superphosphate	Rock phosphate	5.4 : 1	10
Superphosphate	Rock phosphate and manure	3.3 : 1	9
Manure	Manure and superphosphate	4.7 : 1	10
Manure	Rock phosphate	21.6 : 1	10
Manure	Rock phosphate and manure	21.0 : 1	9
Manure and superphosphate	Rock phosphate	34.2 : 1	10
Manure and superphosphate	Rock phosphate and manure	15.9 : 1	9
Rock phosphate and manure	Rock phosphate	2.2 : 1	9

The money value per acre of the increase in yield of rotated corn produced by the several treatments after subtracting the cost of the fertilizer is shown in Table 13. The application of 107 pounds of rock phosphate was the most profitable treatment used, but it produced an average profit of only 48 cents per acre. This treatment was used at a loss two of the five years, but made a small profit the other three years, which resulted in an average gain of 48 cents per acre for the five years. The manure alone produced large enough increases in yield to pay for its cost two of the five years, but the losses during the other three years caused an average loss of 19 cents an acre a year. The other treatments were used at losses ranging from 75 cents to $3.84 per acre for the five years.

Table 13.—Profit or loss per acre attributable to fertilizer treatments on rotated corn.

Fertilizer Treatments	1922	1923	1924	1926	1927	Average
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
100 lbs. cottonseed meal 200 lbs. superphosphate	1.35	0.16	–4.40	2.05	–2.93	–0.75
Crop residues removed	–1.08	–4.40	–2.75	2.58	–1.63	–1.46
200 lbs. superphosphate	0.92	–0.74	–1.64	–2.25	–1.99	–1.14
4 tons manure	2.47	2.90	–1.15	–1.10	–4.09	–0.19
4 tons manure 200 lbs. superphosphate	–7.32	–4.44	–2.79	0.19	–4.84	–3.84
107 lbs. rock phosphate	–0.65	0.85	1.00	1.87	–0.65	0.48
107 lbs. rock phosphate 4 tons manure	–5.23	–1.55	–1.58	–2.77	–5.65	–3.36

Yield of Continuous Corn

The yields secured with corn planted every year on the same land are reported in Table 14. Results were obtained from five of the eight treatments every year of the experiment. The corn was a failure, however, in 1917 and 1925, and consequently no yields are reported for these years.

While the yield of continuous corn is considerably lower than the yield of the corn grown in rotation, the effects of the fertilizer treatments are somewhat similar. The yields produced by the treatments of cottonseed meal with superphosphate and superphosphate with manure were the same, 16.5 bushels per acre, for the 14 years, 1914 to 1927, inclusive. During this period the plat with the crop residues removed produced an average yield of 15.5 bushels per acre, or 1.0 bushel more than the plats which received no treatment, but the difference is not statistically significant according to Student's methods, as shown in Table 15.

Since the treatments of manure, rock phosphate, and manure and rock phosphate were included only during the last six years of the work, average yields were computed for all of the treatments for this period, omitting 1925 because the corn was a failure on account of drouth. The treatments of manure alone, manure with superphosphate, and manure with rock phosphate made almost identical average yields, 18.4, 18.8, and 18.2 bushels, respectively, for the five-year period. Superphosphate with cottonseed meal produced an average yield of 15.1 bushels per acre. Superphosphate produced a slightly smaller average yield than rock phosphate, but the difference in yield was not significant.

The removal of crop residues apparently has not decreased the yield of continuous corn. For the 14 years of the experiment the average yield of the plat with the residues removed was 15.5 bushels per acre as compared with 14.5 bushels for the untreated check plats, the difference being due largely to the higher yield of the former in 1916, 1919, and 1920. The average yields of the plats with the residues removed and the non-treated check plats were identical for the five years, 1922, 1923, 1924, 1926, and 1927.

Table 14.—Yield per acre of continuous corn in fertilizer experiment.

Fertilizer Treatment	1914	1915	1916	1918	1919	1920	1921	1922	1923	1924	1926	1927	Average 14 Years 1914–1927	12 Years 1914–1927*	5 Years 1922–1927†
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
100 lbs. cottonseed meal 200 lbs. superphosphate	13.9	15.0	28.0	16.1	34.9	24.6	22.3	23.4	9.8	6.1	18.5	17.9	16.5	19.2	15.1
Crop residues removed	12.0	14.6	25.4	13.6	38.5	25.5	22.0	21.7	5.2	6.7	15.2	16.1	15.5	18.0	13.0
No treatment—check	11.9	14.3	22.5	14.2	31.5	23.9	20.2	22.5	5.7	5.9	15.9	14.8	14.5	16.9	13.0
200 lbs. superphosphate	14.0	14.8	24.3	16.1	31.7	21.9	27.7	26.6	6.8	5.2	15.2	16.2	15.8	18.4	14.0
4 tons manure	....	....	....	....	....	....	....	32.6	10.9	6.7	21.8	19.9	....	....	18.4
4 tons manure 200 lbs. superphosphate	14.9	14.6	16.2	16.4	33.8	19.4	21.2	27.6	9.9	8.9	24.7	22.8	16.5	19.2	18.8
107 lbs. rock phosphate	....	....	....	....	....	....	....	22.8	12.8	8.0	15.0	13.4	....	....	14.4
107 lbs. rock phosphate 4 tons manure	....	....	....	....	....	....	....	27.4	8.0	12.0	19.7	23.9	....	....	18.2

*Omitting 1917 and 1925. †Omitting 1925.

Table 15.—Comparison by Student's method of yields of continuous corn treated with different fertilizers.

Greater Yield	Smaller Yield	Odds	No. of Years Treatments Were Compared
Cottonseed meal and superphosphate.	Crop residues removed........	8.5 : 1	12
Cottonseed meal and superphosphate.	No treatment...............	4999.0 : 1	12
Cottonseed meal and superphosphate.	Superphosphate............	4.9 : 1	12
Manure and superphosphate.........	Cottonseed meal and superphosphate...............	17.4 : 1	5
Manure and superphosphate.........	Cottonseed meal and superphosphate................	1.0 : 1	12
Cottonseed meal and superphosphate.	Rock phosphate.............	2.0 : 1	5
Cottonseed meal and superphosphate.	Rock phosphate and manure...	17.8 : 1	5
Crop residues removed.............	No treatment...............	16.6 : 1	12
Superphosphate....................	Crop residues removed........	1.0 : 1	12
Manure...........................	Crop residues removed........	51.0 : 1	5
Manure and superphosphate.........	Crop residues removed........	3.2 : 1	12
Rock phosphate....................	Crop residues removed........	3.4 : 1	5
Rock phosphate and manure........	Crop residues removed........	2399.0 : 1	5
Superphosphate....................	No treatment...............	25.3 : 1	12
Manure...........................	No treatment...............	91.2 : 1	5
Manure and superphosphate.........	No treatment...............	19.2 : 1	12
Rock phosphate....................	No treatment...............	3.9 : 1	5
Rock phosphate and manure........	No treatment...............	184.6 : 1	5
Manure...........................	Superphosphate.............	242.2 : 1	5
Manure and superphosphate.........	Superphosphate.............	2.4 : 1	12
Rock phosphate....................	Superphosphate.............	1.4 : 1	5
Rock phosphate and manure........	Superphosphate.............	48.0 : 1	5
Manure and superphosphate.........	Manure....................	1.5 : 1	5
Manure...........................	Rock phosphate.............	11.1 : 1	5
Manure...........................	Rock phosphate and manure...	1.0 : 1	5
Manure and superphosphate.........	Rock phosphate.............	12.7 : 1	5
Manure and superphosphate.........	Rock phosphate and manure...	1.9 : 1	5
Manure and rock phosphate.........	Rock phosphate.............	9.1 : 1	5

As was the case with rotated corn, manure produced the largest yields but not the most profitable returns per acre, as shown in Table 16.

The data in Table 16 show the gains and losses produced by the several fertilizer treatments applied to corn grown on the same land every year. Rock phosphate was the most profitable treatment used, but it made an average gain of only \$1.28 a year above the cost of the material. This gain was largely the result of a gain of \$6.45 in 1923, since the treatment was used at a loss during three of the five years. The removal of crop residues, on the average, did not cause a loss during this period. The treatments of manure with superphosphate and cottonseed meal with superphosphate were the most unprofitable treatments, producing losses of \$2.82 and \$2.63 a year, respectively, for the five years 1922, 1923, 1924, 1926, and 1927.

Comparison of Rotated and Continuous Corn

The average yields of the several fertilizer treatments and the net value of the increase in yield produced by the treatments applied to rotated and continuous corn are given in Table 17.

Table 16.—Money value per acre of the increase in yield of continuous corn produced by fertilizers after subtracting cost of fertilizer.

Fertilizer Treatment	1922	1923	1924	1926	1927	Average
	Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
100 lbs cottonseed meal 200 lbs. superphosphate	-4.13	-0.94	-4.18	-2.21	-1.69	-2.63
Crop residues removed	-0.66	-0.50	0.88	-0.42	0.85	0.03
200 lbs. superphosphate	1.08	-1.24	-2.30	-2.25	-1.21	-1.18
4 tons manure	3.38	0.20	-4.21	-1.46	-1.68	-0.74
4 tons manure 200 lbs. superphosphate	-3.09	-3.14	-4.00	-1.97	-1.92	-2.82
107 lbs. rock phosphate	-0.40	6.45	1.66	-0.65	-0.65	1.28
107 lbs. rock phosphate 4 tons manure	-1.58	-3.35	1.06	-3.37	0.27	-1.39

Table 17.—Comparison of yields and net value of increase produced by fertilizer treatments of rotated and continuous corn.

Fertilizer Treatment	Average Yield of Corn Per Acre				Net Value Per Acre of Increase Produced by Fertilizer Treatment	
	12 Years 1914–1927*		5 Years 1922–1927**			
	Rotated	Con-tinuous	Rotated	Con-tinuous	Rotated	Con-tinuous
	Bushels	Bushels	Bushels	Bushels	Bushels	Bushels
100 lbs. cottonseed meal 200 lbs. superphosphate	30.2	19.2	26.0	15.1	-0.75	-2.63
Crop residues removed	24.7	18.0	20.2	13.0	-1.46	0.03
No treatment—check	25.5	16.9	21.5	13.0	....	....
200 lbs. superphosphate	26.2	18.4	22.7	14.0	-1.14	-1.18
4 tons manure	....	....	27.2	18.4	-0.19	-0.74
4 tons manure 200 lbs. superphosphate	....	....	24.1	18.8	-3.84	-2.82
107 lbs. rock phosphate	....	....	21.4	14.4	0.48	1.28
107 lbs. rock phosphate 4 tons manure	....	....	22.0	18.2	-3.36	-1.39
Average	26.7	18.1	23.1	15.6	-1.47	-1.06

*Omitting 1917 and 1925. **Omitting 1925.

The rotated corn produced decidedly larger yields than the continuous corn. The difference in yield between the rotated and continuous corn is significant in every case, except that of rock phosphate as indicated by the odds calculated by Student's method in Table 18. During the 12 years 1914 to 1927, excluding 1917 and 1925, the rotated corn, as an average of all the treatments, made a yield of 26.7 bushels, while the continuous corn produced 18.1 bushels per acre. This is a gain of 8.6 bushels, or 47.5 per cent, in favor of the rotated corn. The treatment of 4 tons of manure made the largest average yield in rotated corn and the second largest yield in the continuous corn.

Table 18.—Comparison by Student's method of yields of corn grown continuously on the same land and in rotation receiving fertilizer treatments.

Treatment	Greater Yield	Smaller Yield	Odds	No. of Years Treatments Were Compared
Cottonseed meal and superphosphate....	Rotated	Continuous	9999.0 : 1	12
Crop residues removed..................	Rotated	Continuous	3332.0 : 1	12
No treatment...........................	Rotated	Continuous	4999.0 : 1	12
Superphosphate.........................	Rotated	Continuous	1799.0 : 1	12
Manure.................................	Rotated	Continuous	61.1 : 1	5
Manure and superphosphate............	Rotated	Continuous	216.0 : 1	10
Rock phosphate.........................	Rotated	Continuous	13.3 : 1	5
Rock phosphate and manure............	Rotated	Continuous	24.1 : 1	5

The last two columns of Table 17 show the value of the increase in yield produced by the treatments after deducting the cost of the treatment. The cost of the fertilizer materials and the prices used in determining the value of the increase in yield produced by the treatments were given in the discussion of cotton. It will be noted that rock phosphate gave the largest net returns per acre on both rotated and continuous corn. This treatment produced an average gain of 48 cents per acre on rotated corn and $1.28 per acre on continuous corn for the five-year period. The removal of the cotton stalks, corn stalks, etc., from the land did not cause a loss on continuous corn, but resulted in a loss of $1.46 per acre a year on rotated corn.

Yield of Oats in Rotation

The oats used in the fertilizer experiment have been planted in the fall, usually in October or early November. The rate of seeding has varied from 5 to 12 pecks per acre, but in most years the rate of 8 pecks per acre was used. A variety of red rust-proof oats has been used in the experiment, but the same variety has not been grown every year. Texas Red Rust-proof, T. S. No. 1118 was planted in 1916, 1917, and 1923, while another red oat, T. S. No. 1415, was grown in 1926 and 1927. Frazier, T. S. No. 765-13, was grown in 1919, 1920, 1921, and 1922.

The oats were so badly damaged by rust, lodging, and unfavorable weather conditions that yields were not obtained in 1914. In 1915, the oats winter-killed badly and were replanted in March and as a result no yields of grain were obtained. The oats failed on account of rust in 1921 and in 1924 and 1925 on account of unfavorable weather conditions at time of harvest.

In Table 19 are presented the yields of oats secured in the experiment. Low yields were obtained in most years, but fair yields resulted in 1918, 1919, and 1923, considering that the soil is naturally not very productive and the fact that the climatic conditions are not well adapted to small grains. The treatment of 100 pounds of cottonseed meal and 200 pounds

Table 19.—Yield of oats in fertilizer experiment at College Station, 1914 to 1927, inclusive.

Fertilizer Treatment	Acre Yields in Bushels.												
										Average			
	1916	1917	1918	1919	1920	1922	1923	1926	1927	9 Years 1916-27**	14 Years 1914-27	7 Years 1918-27**	4 Years 1922, 23, 26 and 27
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
100 lbs. cottonseed meal 200 lbs. superphosphate.....	16.7	19.1	25.8	42.1	7.0	10.0	32.3	27.8	25.8	23.0	14.8	24.4	24.0
Crop residues removed......	11.6	23.3	31.1	27.5	7.5	9.3	27.8	21.9	17.1	19.7	12.7	20.3	19.0
No treatment..............	14.2	21.9	29.0	30.7	3.1	8.0	21.7	11.9	11.2	16.9	10.8	16.5	13.2
200 lbs. superphosphate.....	15.4	20.6	25.7	17.5	6.0	9.4	26.2	15.3	21.1	17.5	11.2	17.3	18.0
4 tons manure*.............	......	21.4	28.9	30.6	5.8	8.4	20.1	18.8	10.3	....	....	17.6	14.4
4 tons manure* 200 lbs. superphosphate.....	......	18.3	28.2	17.5	5.0	7.0	22.3	16.6	12.2	....	....	15.5	14.5
107 lbs. rock phosphate.....	13.4	18.7	29.2	31.4	1.6	10.1	18.8	11.7	10.2	16.1	10.4	16.1	12.7
107 lbs. rock phosphate* 4 tons manure.............	......	......	33.4	16.7	0.6	7.1	14.5	13.9	2.5	....	....	12.7	9.5

*These treatments were applied to the cotton in the rotation 3 years previous, but since 1921 they have been applied to the oats.
**Omitting 1921, 1924, and 1925.

of superphosphate per acre made the highest yield in each of the following averages: the nine-year average, the 14-year average, the seven-year average, and the four-year average. The higher yield of this treatment apparently is due to the effect of the cottonseed meal, since the application of 200 pounds of superphosphate with or without manure did not produce average yields significantly larger than yields of the non-treated plats or the plats with the residues removed. It is interesting to observe that the plat on which the crop residues were removed made the second largest yield in each of the above averages. There appears to be no consistent relation between yield and the other treatments. The results secured with the different treatments are somewhat variable and conflicting and for this reason it is rather hard to draw definite conclusions from them. It would appear, however, that the soil needs nitrogen before it does phosphoric acid for the production of oats.

Yield of Cowpeas in Rotation

Cowpeas of the Groit variety, T. S. No. 703, were used in this work from 1915 to 1923, inclusive, while Brabham was planted in 1926 and 1927. Only yields of seed were obtained, which are given in Table 19. Satisfactory yields resulted in only one of the 14 years of the experiment, and that was in 1914. The cowpeas did well in 1919, but heavy rains and extended periods of damp, cloudy weather during the harvesting season prevented the harvesting of seed and caused the peas to rot in the field. Consequently, yields were not obtained that year. The cowpeas were a failure in 1924 and 1925 on account of drouth. The yields in the other years were low.

It will be noted that the plats which received no treatment made the highest average yield for the 11-year, the 14-year, and the nine-year periods. In the four-year average the untreated plats and the treatment of manure with superphosphate tied for first place with respect to yield.

From 1922 to 1927, inclusive, all of the treatments were applied direct to the cowpeas. As stated above, the cowpeas failed in 1924 and 1925 on account of drouth. The average yields for the other four years show there was no consistent relation between the treatments and yield. From these results it is not possible to draw definite conclusions about the work except to say perhaps that the treatments used had no effect upon yield.

Discussion of Results

The yields of the crops in these experiments with fertilizers conducted on Lufkin fine sandy loam soil show that the soil did not respond readily to applications of fertilizers. The results indicate, however, that the soil is more deficient in nitrogen and organic matter than it is in phosphoric acid, as shown by the fact that the application of manure alone made about as large yields as manure with superphosphate. The yield resulting from superphosphate was not significantly greater than

Table 20.—Yield of cowpeas in fertilizer experiment at College Station, 1914 to 1927, inclusive.

Fertilizer Treatment	Acre Yield in Bushels														
												Average			
	1914	1915	1916	1917	1918	1920	1921	1922	1923	1926	1927	11 Years 1914-1927**	14 Years 1914-27 incl.	9 Years 1916-1927**	4 Years 1922-23-26-27
	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
100 lbs. cotton seed meal 200 lbs. superphosphate	8.9	5.0	2.3	1.2	0.8	3.2	7.4	2.0	1.8	5.0	6.8	4.0	3.2	3.4	3.9
Crop residues removed	15.8	5.5	2.6	0.7	0.9	3.1	8.0	0.7	3.3	4.9	6.2	4.7	3.7	3.4	3.8
No treatment	9.0	6.6	4.1	0.8	1.3	5.2	7.1	3.2	4.2	5.6	8.3	5.0	4.0	4.4	5.3
200 lbs. superphosphate	14.3	3.9	2.3	0.7	0.9	3.6	3.2	3.2	3.0	5.3	5.3	4.1	3.2	3.1	4.2
4 tons manure*	....	3.6	2.6	0.7	0.9	2.5	7.3	3.9	3.3	6.9	6.0	......	......	3.8	5.0
4 tons manure* 200 lbs. superphosphate	.....	5.6	3.7	0.4	0.8	4.5	8.5	1.7	5.0	7.7	6.6	......	......	4.3	5.3
107 lbs. rock phosphate	.....	2.3	5.4	0.3	0.5	3.5	6.1	0.1	3.5	5.9	7.6	......	......	3.7	4.3
107 lbs. rock phosphate* 4 tons manure	....	.....	4.8	1.2	0.9	1.9	6.9	0.1	4.0	6.7	9.1	......	......	4.0	5.0

*These treatments were applied to cotton the previous year until 1922; from 1922 to 1927, inclusive, they were applied to the cowpeas direct.
**Omitting 1919, 1924, and 1925.

the yield resulting from the plats which received no treatment. When, however, cottonseed meal was added to the superphosphate a significant increase in yield occurred, which is further evidence that the soil is more deficient in nitrogen than it is in phosphoric acid.

In this experiment, rock phosphate produced as large yields as superphosphate. Since the rock phosphate produced as large yields as superphosphate and was much cheaper than the latter, it is clear that rock phosphate was the more profitable material.

The removal of crop residues, such as cotton stalks and corn stalks, reduced slightly but not significantly the productiveness of the soil. This is an interesting fact since it would be expected that the removal of crop residues for a period of 14 years would cause an appreciable and significant decline in the fertility of the soil. These results indicate that this particular soil does not respond readily to the application of fertilizers or to such bad farm practice as removing the crop residues, such as cotton stalks and corn stalks, year after year.

While the results reported here show the Lufkin fine sandy loam responded more readily to nitrogenous fertilizers than it did to phosphatic fertilizers, the work was not comprehensive enough to show definitely the best fertilizer treatments for the particular conditions. The application of manure, however, was the most profitable treatment used.

EFFECT OF ROTATION ON YIELD OF CROPS

The effects of fertilizers on the yield of crops grown in rotation and on crops grown continuously on the same land have been discussed previously. It is desirable at this point to compare directly the yields of the crops grown in rotation with the yield of the same crops grown on the same land every year to show the effect of rotation on yield. Since cotton and corn were the only crops in the experiment that were grown on the same land every year, the study of the effect of rotation on yield will be restricted to these crops.

In comparing the yields of rotated and non-rotated crops, it should be remembered that the fertilizer treatment, variety of crop, seed-bed preparation, planting, cultivation, and harvesting were the same in both systems of cropping. The only difference was that the crop, cotton for example, was grown continuously on the same land in one case, and in rotation with corn, cowpeas, and oats in the other.

Cotton

The average yields of rotated cotton and of continuous cotton for the 13 years, 1914 to 1927, are shown in Table 21. As an average of all the treatments, the rotated cotton made an average yield of 196 pounds per acre, or 24 pounds per acre more than the yield of continuous cotton. This is a clear gain of 14 per cent in favor of the rotated cotton.

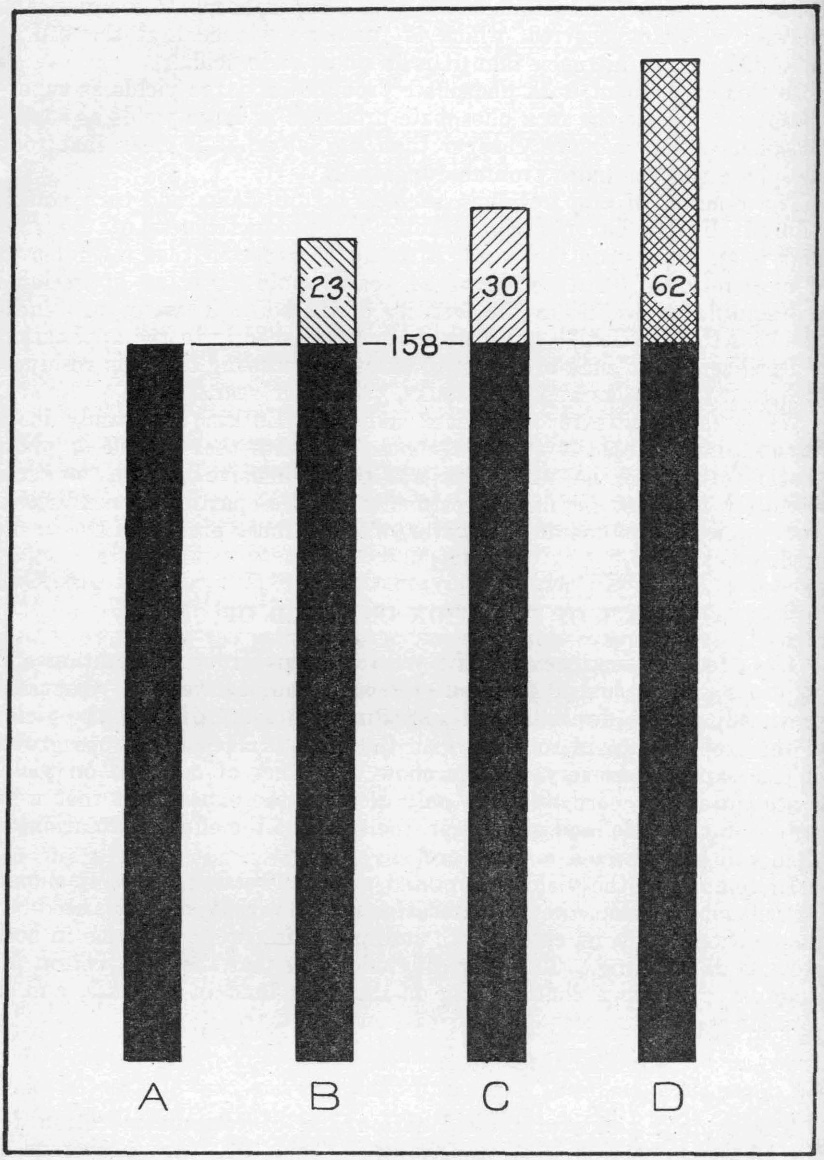

Fig. 1. The yield of cotton grown continuously on the same land, 158 pounds of lint per acre, is shown in A; B shows the increase in yield produced by fertilizer; C shows the increase in yield produced by rotation alone; and D gives the increase in yield resulting from fertilizer and rotation used together.

Table 21.—Average yield in pounds of lint per acre of rotated and continuous cotton for 13 years.

Treatment	Average Yield of Lint Per Acre During 13 Years, 1914-1927*		
	Rotated Cotton	Continuous Cotton	Increase Due to Rotation
	Pounds	Pounds	Pounds
100 lbs. cottonseed meal 200 lbs. superphosphate	205	181	24
Crop residues removed	175	154	21
No treatment—check	188	158	30
200 lbs. superphosphate	190	186	4
4 tons manure 200 lbs. superphosphate	220	181	39
Average	196	172	24

*Omitting 1920 on account of failure of rotated cotton.

Figure 1 shows the effect of rotation and fertilizer on the yield of cotton. The yield of continuous cotton, 158 pounds of lint per acre, is shown in A of Figure 1, and may be considered as the effect of tillage on yield. The unfertilized cotton in rotation made an average yield of 188 pounds of lint per acre, or 30 pounds per acre more than the unfertilized cotton grown continuously on the same land, as shown in C. Continuous cotton, where fertilized with manure and superphosphate, produced 181 pounds of lint per acre, or 23 pounds per acre more than the yield of continuous cotton which received no treatment, as indicated in B. This represents the effect of fertilizer alone on the yield of cotton. Rotated cotton which was fertilized made an average yield of 62 pounds of lint per acre more than continuous cotton which received no fertilizer, as shown in D of Figure 1. This increase of 62 pounds is the combined effect of rotation and fertilizer on the yield of cotton. The increase caused by rotation and fertilizer combined is greater than the sum of the increases produced by rotation and fertilizer used separately.

Corn

The average yields of rotated and of continuous corn for 12 years are given in Table 22. During this period the rotated corn, considering all of the treatments, made an average yield of 26.7 bushels per acre, or 8.6 bushels per acre more than the yield of continuous corn. This increase of 8.6 bushels represents an increase of 47.5 per cent over the yield of continuous corn. The rotated corn in the case of every treatment made considerably higher average yields than continuous corn with the same treatment.

The increases in yield of corn due to rotation and to the use of fertilizer are shown in Figure 2. The yield of continuous corn, 16.9 bushels per acre, is shown graphically in A of Figure 2. This yield may be considered as the result of tillage alone. The unfertilized corn

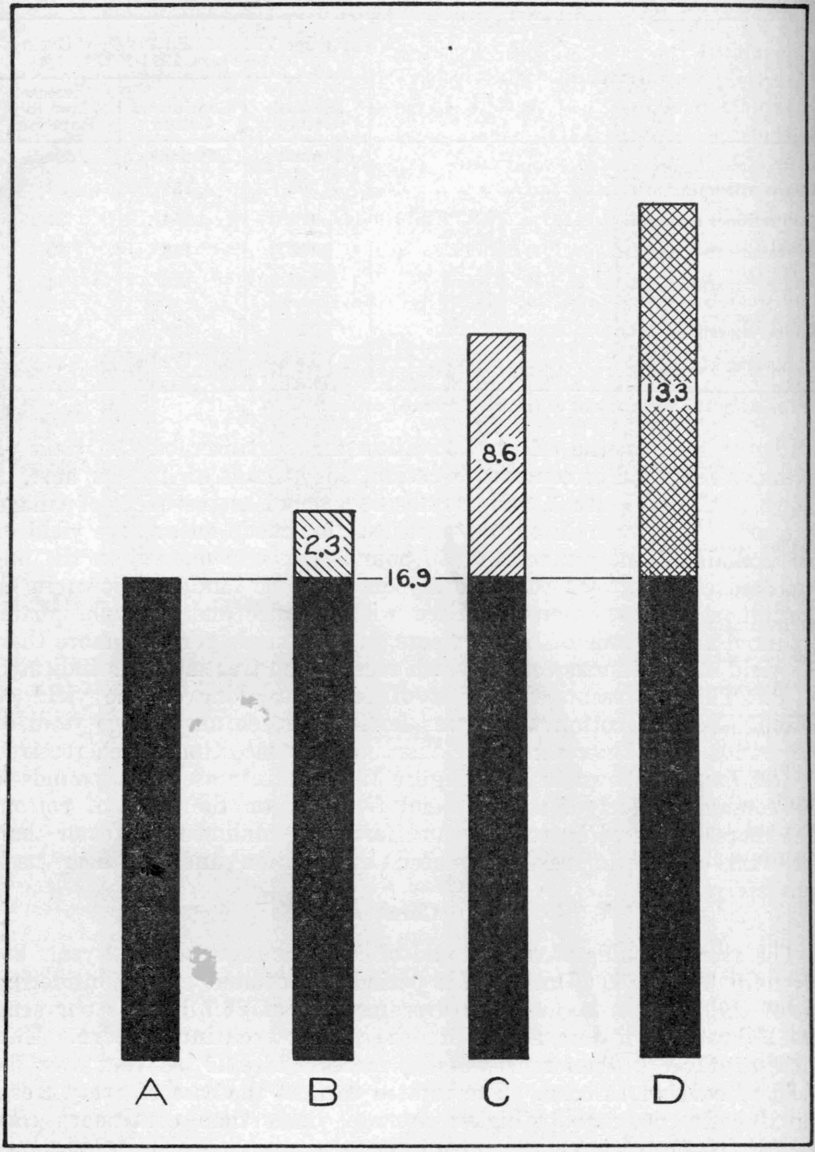

Fig. 2. The yield of corn grown on the same land every year, 16.9 bushels per acre, is represented by A; B shows the increase in yield made by fertilizer; C shows the increase in yield produced by rotation; while D gives the increase in yield produced by fertilizer and rotation when used together.

in rotation made an average yield of 25.5 bushels per acre, or 8.6 bushels more than unfertilized continuous corn, as shown in C. When the continuous corn was fertilized (with cottonseed meal and super-phosphate) the yield was increased 2.3 bushels per acre, as shown in B; this yield represents the effect of fertilizer on the yield of corn. Corn in rotation which was fertilized produced an average yield of 30.2 bushels per acre, or 13.3 bushels more than the yield of unfertilized corn grown continuously on the same land (D, Figure 2). This represents the combined effect of rotation and fertilizer on the yield of corn. The results above show clearly that the increase in yield produced by the rotation was nearly four times as large as the increase produced by fertilizer alone. The increase resulting from the joint use of rotation and fertilizer was greater than the sum of the increases produced by rotation and fertilizer separately.

Table 22.—Average yield in bushels per acre of rotated and continuous corn for 12 years.

Treatment	Average Yield in Bushels Per Acre for 12 Years, 1914-1927*		
	Rotated Corn	Continuous Corn	Increase Due to Rotation
	Bushels	Bushels	Bushels
100 lbs. cottonseed meal 200 lbs. superphosphate	30.2	19.2	11.0
Crop residues removed	24.7	18.0	6.7
No treatment—check	25.5	16.9	8.6
200 lbs. superphosphate	26.2	18.4	7.8
Average	26.7	18.1	8.6

*Years 1917 and 1925 omitted on account of failure.

The results obtained with cotton and corn show that rotation of crops is conducive to the more efficient use of fertilizers. Rotation increased the yield of these crops more than the fertilizers, but the best results were obtained by the combined use of rotation and fertilizers.

THE VALUE OF CROPS IN ROTATION

The effect of fertilizers and rotation on the yield of crops and the profits derived from the use of fertilizers have already been discussed. It now remains to show the money value of crop rotation by comparing the value of the crops grown in rotation with the value of the same crops grown continuously on the same land.

It is desirable to know the cost of producing the crops and the profits that may be reasonably expected in order that the farmer may make an intelligent choice of his farm enterprise, including the proper use of fertilizers, rotation of crops, and the most efficient utilization of these crops. Accordingly, the total value per acre, the cost of production, and the net returns per acre of the four crops, cotton, corn, oats, and cowpeas, were determined. In computing the value of the crops the estimated prices of cotton, corn, and oats as received by producers on December 1 of each year, as given in the Yearbooks of the United States Department of Agriculture, were used. The value of the oat crop included both grain and straw, the latter being valued at $10.00 a ton, which was the average price per ton of straw sold. The cowpeas were figured at $3.00 a bushel, which was the average price received for the cowpeas. The total cost of producing the crops was based largely on figures obtained in detail cost studies made by the Division of Farm and Ranch Economics of this Station, in Rockwall and Collin counties in 1925 and 1926. The cost of production of the crops includes all expenses incurred in actually producing and harvesting the crops and preparing them for market.

Table 23 gives the average yearly gross returns per acre, cost of production, and average net return per acre of cotton, corn, oats, and cowpeas for the four years 1922, 1923, 1926, and 1927. Rotated cotton made the largest profit, $22.11 per acre, which, however, was only slightly more than the profit of the continuous cotton. Continuous corn gave the smallest profit, which was only $1.52 per acre.

Table 23.—Average value per acre of cotton, cowpeas, corn, and oats for the four years, 1922, 1923, 1926, and 1927.

Kind of Crop	Gross Returns Per Acre	Cost of Production Per Acre	Net Returns Per Acre
Continuous cotton	$ 41.49	$ 19.74	$ 21.75
Continuous corn	10.89	9.37	1.52
Rotated cotton	41.59	19.48	22.11
Rotated corn	16.77	10.17	6.60
Rotated cowpeas	15.90	13.16	2.74
Rotated oats	13.54	8.24	5.30
Average for rotated crops	....	....	$ 9.19

The average net returns of the four crops, cotton, cowpeas, corn, and oats, grown in rotation was $9.19 per acre a year for the four years. The continuous cotton made a profit of $21.75 per acre a year. This shows clearly that this particular rotation was not as profitable as continuous cotton and is not recommended to the farmers in the region.

While the crops in the four-year rotation did not produce as large an average net return per acre as continuous cotton, the data in Table 23 are valuable in showing the value per acre of the several crops. These data show that cotton had a higher value per acre than the other crops. The table also shows that cowpeas, when grown for seed as they were in this experiment, were not profitable and consequently should not be used for this purpose in a rotation in this region. Corn and oats produced much smaller net returns per acre than cotton. Although corn has a rather low value per acre on the basis calculated, it is one of the best grain crops for this part of the State and should be included in the cropping system, for the reason that it may be planted, cultivated, and partially produced at a time when the farm labor and equipment would not be used in producing cotton. Furthermore, the corn produced and fed on the farm may be valued at the retail price of corn, that is, the price the farmer would pay if he were to buy the corn, which would be considerably more than the farm price of corn used in calculating the acre value of corn in Table 23. This simply means that if the corn grown on the farm is fed to the farm livestock, the acre value of the corn crop will be greater than the value of the crop computed on the basis of the farm price as was done in the above table.

While the four-year rotation of cotton, cowpeas, corn, and oats was not profitable, largely on account of the low value of the cowpeas, a two-year rotation of cotton and feed crops (corn as the grain crop and sorgo, Sudan grass, or cowpeas for hay) should be satisfactory. As a rule, a rotation should include a legume such as cowpeas or vetch on account of their soil-enriching properties. The legume should be used as a feed or cash crop if it is grown during the regular growing season because it is worth more as a feed crop than it is for soil improvement. If the legume is cut for hay, the residues including the stubble or manure resulting from grazing the stubble or aftermath (second growth), should be plowed under to improve the land. Catch crops, such as cowpeas planted on oat stubble, cowpeas planted in corn at the last cultivation of the corn, or winter cover crops such as vetches may be plowed under for soil improvement or they may be grazed off and the residues plowed under.

It should be pointed out here that it is a sound business policy for the farmer to produce all the feed he needs for his livestock. After the required feedstuffs have been provided, he may devote his attention to the growing of cotton. The cropping system then may be conveniently called a two-year rotation of cotton and feed crops, as mentioned above. This two-year rotation does not require that one-fourth, one-third, or one-half of the land be devoted to each crop grown. It merely requires that enough feed crops be grown to furnish the feed required by the livestock on the farm. The feed crops should be planted each year on land that grew cotton the previous year. The cotton would be planted on the remaining land not in other crops.

Since it is good business policy to produce the feed required on the farm and since rotation increases the yield of crops, it follows that the crops that are grown should be included in a rotation. It is clear, therefore, that a rotation costs the farmer nothing and the larger yields resulting from the rotation represent so much gain or profit.

In operating a farm as a business enterprise, the farmer should bear in mind that usually there is a certain amount of labor and equipment, such as work stock and machinery, available on the farm during the year. If the one-crop system, whether it consists of cotton, corn, or other crops, is practiced there will be times when the labor and equipment will be idle and consequently non-productive. If suitable rotations are used, two or more crops may be grown and, as a result, the labor may be distributed to a better advantage. In the two-year rotation of cotton and feed crops mentioned above, the corn may be planted a month or six weeks earlier than cotton. The land may be prepared for corn and the corn planted at a time that would not interfere with the planting of cotton. In this way, the labor and equipment may be used to grow feed or cash crops other than cotton at times when they could not be used to produce cotton, which would of course result in a larger income.

In this connection it should be emphasized that the proper distribution of labor during the year is one of the main factors in making farming profitable. While it is shown above that cotton makes larger profits per acre than the other crops, yet the more suitable feed crops may be grown to advantage because they may be produced at a time when the labor and equipment would not be used in the production of cotton. The result is that the income from these crops may be considered largely as profit, since the labor and equipment would not have been used if the one-crop system had been followed.

SUMMARY

These experiments with fertilizers were conducted on Lufkin fine sandy loam, which is an extensive soil in certain parts of southeastern Texas. Associated with this soil are other soils somewhat related in character to which these results will probably also apply to a considerable extent.

Nitrogenous materials, manure and cottonseed meal, produced larger increases in yield of cotton and corn than phosphoric acid, which indicates that the soil is more deficient in nitrogen than it is in phosphoric acid.

Application of four tons of manure per acre each year to cotton produced the largest yields and the greatest profits over a period of six years, when both rotated and continuous cotton are considered. Rock phosphate, however, made a slightly larger profit per acre on continuous cotton than did manure.

Rock phosphate and superphosphate were equally effective in increasing the yield of cotton and corn. Since the rock phosphate is the cheaper of the two materials, it was the more profitable.

Manure in combination with rock phosphate increased the yields of cotton and corn but it was used at a loss on both of these crops over a period of years. Manure and superphosphate, however, when applied to rotated cotton made an average gain of $4.42 per acre above its cost, for the six years 1922 to 1927.

The removal of the crop residues (cotton stalks and corn stalks, etc.) caused a slight but not a significant decline in the productiveness of the soil.

The fertilizers apparently did not increase the yield of either oats or cowpeas.

Rotation increased the yield of cotton 14 per cent and the yield of corn 47.5 per cent. The rotated cotton and continuous cotton were about equally profitable, returning a profit of \$22.11 and \$21.75 per acre, respectively, above the cost of production, over a period of four years. Rotated corn gave an average net return of \$6.60 per acre. Corn grown continuously on the same land made a profit of only \$1.52 per acre. The average net return of the four crops in the rotation was \$9.19 as compared with \$21.75 per acre for continuous cotton.

ACKNOWLEDGMENTS

The experiment was established in 1914 by Mr. A. H. Leidigh, then Agronomist, who had charge of the work up to 1920, after which the author assumed charge. Mr. D. T. Killough, former superintendent, and Mr. G. T. McNess, Superintendent of the Main Station Farm, conducted the field work and collected data after 1923.